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Genetic variability and correlation studies among morphological traits in garlic (*Allium sativum* L.)

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ABSTRACT

Thirty-four genotypes of garlic were evaluated at Vegetable Research Station of C. S. Azad University of Agriculture and Technology, Kalyanpur, Kanpur during rabi season of 2018-19 to study the genetic variability as well as an association for 18 yield and yield developmental characters. A wide range of variation was observed for most of the characters like total bulb yield, marketable bulb yield, plant height, average weight of bulb, days to maturity, number of cloves bulb^{-1}, average weight of cloves bulb^{-1}, leaf length and dry matter content. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the traits studied, indicating influence of environment in the expression of these traits. Average weight of cloves bulb^{-1}, average weight of bulb and plant height had a high phenotypic and genotypic coefficient of variations coupled with high estimates of heritability and expected genetic advance. The marketable bulb yield had a significant positive correlation with characters viz., total bulb yield, width of cloves, average weight of bulb, number of leaves plant^{-1}, days to maturity and average weight of cloves bulb^{-1} indicating that selection based on these traits will help to increase the yield of garlic.

Key Words: Correlation, genetic variability, PCV, GCV, heritability and genetic advance

INTRODUCTION

Garlic (*Allium sativum* L.) is one of the most important and prominent vegetable crop belong to the family Alliaceae. It is the second most widely used cultivated *Alliums* after onion. It is an herbaceous annual, the underground edible stem of which is a composite bulb made up of a numerous smaller bulbs known as cloves, covered with pinkish or whitish skin. Garlic cloves are regularly consumed almost in every home, not for culinary purposes but also in home remedies and flavouring agent in many processed food as garlic paste, powder, pearls, pharmaceutical etc. It has long been recognized all over the word as a valuable spice for food and popular remedy for various ailment physiological disorders. The garlic is commercially important and export oriented crop for foreign exchange earner from the fresh and processed products along with to high increased demand in India. India is the second largest producer of garlic in the world after China and occupies an area under is 352.13 thousand hectares with a production of 2944.16 thousand metric tones and productivity of 8.36 tone per hectare (Anonymous, 2019). In Uttar Pradesh, garlic is extensively cultivated in the area of 34.31 thousand hectares with a production of 227.34 thousand metric tones with a productivity of 6.63 tone per hectare (Anonymous, 2019). Although the productivity is low in India as well as in Uttar Pradesh, may be attributed to non-availability of quality genuine planting materials, lack of disease resistant/tolerant varieties and inadequate crop management practices; consequently it needs critical attention to improve the yield and quality of this crop. Yield is a complex character governed by several other yield attributing traits that are generally quantitatively inherited and highly influenced by the environment. Thus, it is difficult to judge what proportion of observed variability is heritable. Therefore, the primary variability parameters like genotypic variance, phenotypic variance, genetic advance, and heritability are useful in understanding the nature of variability and inheritance of different traits. A study of correlation between different quantitative characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving the yield of a crop. In order to have more clear picture of yield components for effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. The objective of the present study was to assess the genetic architecture of yield and its components among thirty-four genotypes of garlic.

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MATERIAL AND METHODS

The present investigation was carried out in the experimental field of the Vegetable Research Station, C. S. Azad University of Agriculture and Technology, Kalyanpur, Kanpur during *rabi* 2018-19. The experimental material for the present investigation was comprised of thirty-four diverse genotypes of garlic (eight recommended varieties and twenty-six local cultivar/landraces) was evaluated in a randomized complete block design with three replications. In each replication, each genotype was represented by a plot having 20 rows of 3 meter long. All the recommended cultural practices were followed throughout the crop life cycle. A random sample of ten competitive plants of each genotype was taken and data recorded from each plot replication wise for plant height (cm), number of leaves^{-1}, leaf length (cm), leaf width (cm), pseudostem length (cm) and pseudostem diameter (cm) at 80 to 90 days after planting. Yield and yield developmental characters like days to maturity, polar diameter (cm), equatorial diameter (cm), number of cloves^{-1}, average weight of bulb (g), average weight of 10 cloves, length of cloves (cm), width of cloves (cm), total bulb yield (q ha^{-1}), marketable bulb yield (q ha^{-1}), total soluble solids (%) and dry matter content (%) were recorded on ten random selected plants after harvesting. The crop was harvested when there was either neck-fall or all of the leaves showed senescence. Analysis of variance was carried out based on the method as suggested by Panse and Sukhatme (1967). The phenotypic and genotypic coefficients of variation (PCV and GCV), heritability in broad sense and genetic advance as percent of mean were calculated as per the procedures given by Burton and De Vane (1953) and Johnson *et al.* (1955). The correlation co-efficient among all possible character combinations at genotypic (rg) and phenotypic (rp) levels were estimated employing the formula given by Al-Jibouri *et al.* (1958).

RESULTS AND DISCUSSION

The mean sum of squares due to genotypes were highly significant for all the eighteen characters under study (Table 1) which indicated that the genotypes included in the study were a genetically diverse and a considerable amount of variability was present in the experimental material. The estimates of variability *viz*., mean, range, variance, phenotypic coefficient variation (PCV) and genotypic coefficient variation (GCV), heritability (in broad sense) and genetic advance as percent of mean (genetic gain) were worked out to facilitate selection for various characters. The results obtained for different parameters of variability are presented in Table 2. The range of variation was highest for total bulb yield (44.55 to 134.77 q ha^{-1}) followed by marketable bulb yield (41.96 to 123.20 q ha^{-1}), plant height (46.23 to 83.76 cm), average weight of bulb (13.94 to 42.60 g), days to maturity (138.00 to 157.33), number of cloves bulb^{-1} (20.10 to 39.07 g), average weight of cloves bulb^{-1} (6.33 to 22.53 g), leaf length (35.03 to 50.52 cm) and dry matter content (29.33 to 44.67 %) indicating the presence of sufficient amount of variability among the genotypes used in the present investigation. The estimates of phenotypic coefficient variation (PCV) and genotypic coefficient variation (GCV) depicted a clear picture of the extent of variability present in the available genotypes. Coefficients of variability varied in magnitude reflecting a substantial variation for all the characters in the experimental material used. The phenotypic and genotypic coefficients of variation were higher for average weight of cloves bulb^{-1} (30.47 and 28.59, respectively), average weight of bulb (30.00 and 28.47) and plant height (20.49 and 20.07). Similar results were reported by Sharma *et al.* (2016) for plant height and Meena *et al.* (2020) for bulb weight and average weight of cloves in garlic. The moderate values for PCV and GCV were exhibited by total bulb yield (19.90 and 17.05, respectively) followed by the number of cloves bulb^{-1} (15.45 and 13.61), equatorial diameter (15.36 and 14.45), polar diameter (13.57 and 12.61), number of leaves^{-1} (13.52 and 12.50) and leaf width (11.38 and 10.10). The traits pseudostem length, dry matter content, leaf length and days to maturity had moderate values of PCV and low values of GCV. Relative magnitude of studied, phenotypic coefficients of variation were higher than the corresponding genotypic coefficients of variation, though the difference was less in the majority of cases thus, indicating that environmental factors have negligible influence on the expression of these characters.

Table 1: Analysis of variance of all 18 characters for 34 genotypes in garlic

Characters	Mean sum of squares			SE(d)	CV (%)
	Replications (*df* = 2)	Genotypes (*df* = 33)	Error (*df* = 66)		
Plant height (cm)	11.62	465.05**	6.49	2.08	4.13
Number of leaves per plant	0.26	2.63**	0.14	0.30	5.13
Leaf length (cm)	7.28	55.60**	3.73	1.57	4.59
Leaf width (cm)	0.03	0.12**	0.01	0.083	5.23
Pseudostem length (cm)	19.16	13.64**	2.06	1.17	7.10
Pseudostem diameter (cm)	0.00	0.015**	0.00	0.025	2.58
Days to maturity	9.62	58.93**	11.1	2.72	2.23
Polar diameter (cm)	0.01	0.65**	0.03	0.14	5.01
Equatorial diameter (cm)	0.00	0.97**	0.04	0.16	5.20
Number of cloves per bulb	15.51	49.67**	4.37	1.70	7.32
Average weight of bulb (g)	27.29	163.08**	5.81	1.96	9.48
Average weight of 10 cloves (g)	0.00	32.45**	1.41	0.96	10.55
Length of cloves (cm)	0.01	0.15**	0.02	0.11	5.85
Width of cloves (cm)	0.007	0.048**	0.004	0.057	7.06
Marketable bulb yield (q/ha)	65.18	1078.56**	106.68	8.43	11.15
Total bulb yield (q/ha)	100.56	1097.37**	118.22	8.87	10.25
Total soluble solids (%)	2.64	19.41**	5.69	1.94	5.14
Dry matter content (%)	2.99	41.43**	5.19	1.86	5.98

***significant at 0.01 probability level*

High heritability (>60 %) indicates that a large proportion of phenotypic variance is attributed to genotypic variance, and reliable selection could be made for the characters based on phenotypic variation. In the present study, all the traits expressed high heritability except days to maturity and total soluble solids.

Table 2: Genetic variability parameters of bulb yield and yield developmental characters in garlic

Characters	Grandmean	Ranges		PCV	GCV	h^2_b	GA	GAM
		Min.	Max.					
Plant height (cm)	61.60	46.23	83.76	20.49	20.07	95.9	51.37	83.39
Number of leaves per plant	7.29	5.87	9.40	13.52	12.50	85.6	3.58	49.10
Leaf length (cm)	42.06	35.03	50.52	10.90	9.88	82.2	16.00	38.04
Leaf width (cm)	1.95	1.46	2.53	11.38	10.10	78.8	0.74	37.94
Pseudostem length (cm)	20.21	16.77	26.02	12.04	9.72	65.2	6.73	33.30
Pseudostem diameter (cm)	1.21	1.09	1.34	6.25	5.70	83.0	0.26	21.48
Days to maturity	149.56	138.00	157.33	10.46	8.67	58.8	12.97	8.67
Polar diameter (cm)	3.60	2.84	4.81	13.57	12.61	86.4	1.79	49.72
Equatorial diameter (cm)	3.86	3.05	5.31	15.36	14.45	88.5	2.22	57.51
Number of cloves per bulb	28.55	20.10	39.07	15.45	13.61	77.5	14.52	50.85
Avg. weight of bulb (g)	25.43	13.94	42.60	30.00	28.47	90.0	29.14	114.58
Avg. weight of 10 cloves (g)	11.25	6.33	22.53	30.47	28.59	88.0	12.81	113.86
Length of cloves (cm)	2.46	2.11	2.95	3.48	2.67	68.7	0.74	30.08
Width of cloves (cm)	0.99	0.73	1.24	2.83	2.11	74.7	0.45	45.45
Marketable bulb yield (q/ha)	92.62	41.96	123.20	22.40	19.43	75.2	66.24	71.51
Total bulb yield (q/ha)	105.98	44.55	134.77	19.90	17.05	73.4	65.69	61.98
Total soluble solids (%)	46.39	41.14	50.92	6.91	4.61	44.6	6.05	13.04
Dry matter content (%)	38.10	29.33	44.67	10.91	9.12	69.9	12.33	32.36

PCV = phenotypic coefficient of variation, GCV = genotypic coefficient of variation, h^2_b= heritability (in broad sense) GA = genetic advance, GAM=genetic advance as percentage of mean

The highest magnitude of heritability was observed for plant height (95.9 %), average weight of bulb (90.0 %), equatorial diameter (88.5 %), average weight of cloves per bulb

Table 3: Phenotypic (r_p) and genotypic (r_g) correlation coefficients among the characters in garlic * and ** indicates significance of values at P=0.05 and P=0.01, respectively

Characters		NOL	LL	LW	PL	PD	P	E	NOC	ABW	AWC	CL	CW	DTM	TBY	TSS	DM	MBY
PH	rp	0.621**	0.804**	0.252*	0.625**	0.159	0.560**	0.628**	0.490**	0.713**	0.671**	0.536**	-0.052	-0.022	-0.100	0.014	-0.474**	0.037
	rg	0.659**	0.881**	0.280**	0.702**	0.169	0.630**	0.671**	0.563**	0.777**	0.732**	0.666**	-0.067	-0.003	-0.116	0.039	-0.576**	0.048
NOL	rp		0.588**	0.520**	0.380**	0.000	0.323**	0.403**	0.269**	0.512**	0.452**	0.320**	0.255**	-0.072	0.141	0.081	-0.417**	0.197*
	rg		0.629**	0.545**	0.418**	0.038	0.390**	0.460**	0.342**	0.590**	0.494**	0.340**	0.279**	-0.109	0.166	0.132	-0.556**	0.244*
LL	rp			0.396**	0.363**	0.142	0.543**	0.612**	0.342**	0.729**	0.716**	0.457**	0.014	0.167	-0.050	0.081	-0.439**	0.091
	rg			0.468**	0.389**	0.166	0.693**	0.725**	0.443**	0.864**	0.833**	0.623**	-0.081	0.279**	-0.039	0.077	-0.547**	0.127
LW	rp				0.061	0.055	0.548**	0.512**	0.216*	0.446**	0.397**	0.159	-0.081	0.111	0.128	-0.056	-0.148	0.149
	rg				0.049	0.054	0.720**	0.645**	0.302**	0.524**	0.448**	0.118	-0.160	0.111	0.183	-0.074	-0.212*	0.205*
PL	rp					0.090	0.261**	0.298**	0.457**	0.339**	0.291**	0.227*	-0.114	-0.265**	-0.103	-0.067	-0.289**	-0.034
	rg					0.072	0.408**	0.387**	0.637**	0.466**	0.387**	0.321**	-0.187	-0.288**	-0.119	-0.073	-0.386**	-0.019
PD	rp						-0.077	-0.019	0.087	0.202*	0.154	0.117	-0.071	-0.088	-0.062	-0.059	-0.070	-0.144
	rg						-0.034	-0.016	0.120	0.209*	0.151	0.086	-0.116	-0.116	-0.111	-0.152	-0.100	-0.206*
P	rp							0.867**	0.446**	0.610**	0.592**	0.307**	-0.320**	0.183	-0.119	-0.031	-0.389**	0.027
	rg							0.954**	0.509**	0.699**	0.686**	0.396**	-0.362**	0.252*	-0.184	0.025	0.535**	0.018
E	rp								0.390**	0.745**	0.738**	0.354**	-0.208*	0.229*	-0.027	-0.011	-0.465**	0.114
	rg								0.483**	0.842**	0.837**	0.509**	-0.259**	0.305**	-0.017	-0.040	-0.604**	0.170
NOC	rp									0.445**	0.211*	0.057	-0.204*	-0.122	0.023	-0.097	-0.286**	0.023
	rg									0.510**	0.292**	0.068	-0.239*	-0.053	0.057	-0.064	-0.333**	0.067
ABW	rp										0.857**	0.479**	-0.020	0.208*	0.215*	-0.077	-0.423**	0.299**
	rg										0.929**	0.585**	-0.017	0.285**	0.215*	-0.117	-0.541**	0.331**
AWC	rp											0.529**	0.043	0.282**	0.121	-0.125	-0.459**	0.242*
	rg											0.628**	0.007	0.411**	0.082	-0.255**	-0.615**	0.238*
CL	rp												0.248*	0.077	-0.024	0.071	-0.108	0.062
	rg												0.279**	0.188	-0.001	0.074	-0.207*	0.109
CW	rp													0.071	0.324**	-0.018	-0.029	0.287**
	rg													0.169	0.451**	-0.201*	-0.028	0.413**
DTM	rp														0.205*	-0.133	-0.029	0.258**
	rg														0.157	-0.342**	-0.229*	0.240*
TBY	rp															-0.073	0.216*	0.934**
	rg															-0.106	0.199*	0.941**
TSS	rp																0.164	-0.026
	rg																0.175	-0.058
DM	rp																	0.126
	rg																	0.086
MBY	rp																	-
	rg																	-

PH=Plant Height (cm); NL/P= Number of Leaves/plant; ; LL=Leaf Length (cm); LW=Leaf Width (cm); PL=Pseudo Stem Length (cm); P=Polar Diameter (cm); E=Equatorial Diameter (cm); NOC=Number of Cloves/Bulbs ABW= Average Bulb Weight (g); AWC= Average Weight of 10 Cloves; CL=Length of Cloves; CW=Width of Cloves; DTM=Days to maturity; TBY= Total Bulb Yield (q/ha); TSS=Total Soluble Solids (%); DM=Dry Matter (%); MBY=Marketable Bulb Yield (q/ha)

(88.0 %), polar diameter (86.4 %), number of leaves^{-1} (85.6 %), pseudostem diameter (83.0 %), leaf length (82.2 %), leaf width (78.8 %), number of cloves bulb^{-1} (77.5 %), marketable bulb yield (75.2 %), width of cloves (74.7 %), total bulb yield (73.4 %), dry matter content (69.9 %), length of cloves (68.7 %) and pseudostem length (65.2 %) suggesting the important role of the genetic constitution in the expression of the characters and such traits are considered important from a breeding point of view. These findings are in close conformity with the reports of Sonkiya *et al.* (2012), Dhall and Brar (2013), Jethava *et al.* (2018) and Meena *et al.* (2020). The higher magnitude of genetic advance as per cent of mean was observed for most of the characters except leaf length (38.04), leaf width (37.94), pseudostem length (33.30), dry matter content (32.36) and length of cloves (30.08) exhibiting moderate one. High heritability suggested the major role of the genetic constitution in the expression of characters and such performance of characters are considered to be repeatable. However, the estimates of heritability alone are not sufficient for predicting the effect of selection and therefore the genetic advance/gain is also equally important (Hanson and Earle, 1995).

A correlation coefficient is estimated between yield and developmental character at phenotypic and genotypic levels to know the interrelationship among the characters. It provides information about the nature, extent of association and direction of selection pressure to be applied. The higher magnitude of almost genotypic correlation coefficient compared to their corresponding phenotypic coefficients value indicated inherent association among all combinations of traits studied and presented in Table 3.

From these, associations, it appeared that higher marketable bulb yield (q ha^{-1}) had significant and positive correlation with total bulb yield (rp= 0.934 and rg= 0.941, respectively), clove weight (rp= 0.287 and rg= 0.413), average weight of bulb (rp= 0.299 and rg= 0.331), number of leaves plant^{-1} (rp= 0.197 and rg= 0.244), days to maturity (rp= 0.258 and rg= 0.240), average weight of cloves (rp= 0.242 and rg= 0.238) indicated that these characters are the primary yield determinants in garlic and could be improved through direct selection. These findings support the earlier findings of Sonkiya *et al.* (2012), Gehani and Kanbar (2013), Singh *et al.* (2013), Bhatt *et al.* (2017), Gebremichael (2019). On the other hand, marketable bulb yield exhibited non-significant negative correlation with pseudostem length and total soluble solids at both phenotypic and genotypic levels. Based on this study, it can be concluded that selection would be rewarding for high value of PCV, GCV, heritability and genetic gain to bring out the improvement in the garlic. The present association studies among various traits at phenotypic and genotypic levels showed that marketable bulb yield had positive and highly significant association with total bulb yield, width of cloves and average weight of bulb are reflecting the importance of these characters for component breeding. Selection for these traits might be fruitful for improvement of bulb yield in garlic.

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